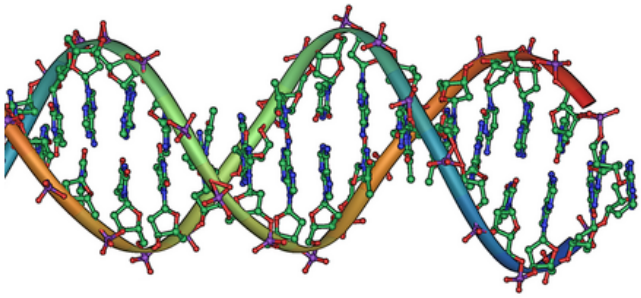
With support from Oxfordshire County Council,

Science Oxford is pleased to present

Dissecting DNA

The Science of DNA and Genetics

STEM Club Resource Pack



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Introduction:

DNA (deoxyribonucleic acid) is found in every cell in your body. It contains vital information that is passed on from generation to generation. It can coordinate the making of itself as well as other molecules. If your DNA is altered in any way, serious ramifications may occur. If the DNA is destroyed the cell also dies.

In biomedical science, learning more about our genetic information could lead to more understanding of and finding cures for many genetic diseases. Anthropology is the study of humans past and present and has allowed us to study DNA from sample primates. In forensics, the presence or absence of DNA evidence at a crime science can completely alter the verdict and outcome of an investigation. DNA can also lead the way towards cloning; from one cell you can gather enough DNA to clone an animal, a plant or even a person.

Through a series of investigations, you will;

- Extract DNA
- Make DNA models
- Run an electrophoresis experiment
- Look at our own genetic traits
- Investigate genetics in evolution and natural selection

Suggested Timetable:

Week 1 - Extracting DNA

DNA extraction from strawberries

Week 2 – Making DNA Models

Sweetie models of the DNA double helix

Week 3 – Electrophoresis Part 1

Forensic DNA Investigation

Week 4 – Electrophoresis Part 2

Forensic DNA Investigation

Week 5 – All About You! Investigating our own genes and senses

How do your genes affect your senses?

Week 6 – Evolution and Variation

How does evolution work in the real world?

Week 7 – Clippy Island

Explore the concept of "Survival of the Fittest"

Week 1: Extracting DNA

Equipment needed:

Beakers	Water
spoons	Washing up liquid
Isopropyl rubbing alcohol, 70%	Small bowl
Salt	J cloth
Funnel	Plastic Ziploc bags
Strawberries	Test tube
Bamboo skewers	Pipette

What to do:

- Chill the rubbing alcohol in a freezer
- Make the extraction liquid by mixing half a teaspoon of salt with one tablespoon of washing up liquid with 80ml of water.
- Line a funnel with the J cloth and place it over a beaker.
- Remove the stalks from three strawberries, and put them in a Ziploc bag.
- Make sure there is no air trapped in the bag and then squash the strawberries, until they have formed a puree.
- Add 3 tablespoons of the extraction liquid to the strawberries in the bag. Make sure you push out any more trapped air.
- Squash the strawberry mixture around some more, the consistency should change slightly.
- Pour the strawberry mixture through the J cloth in the funnel. It will take a while for all the liquid to seep through the cloth. Make sure no thick pulp gets into the beaker below.
- Once the majority of the liquid has seeped through, you can throw away the J cloth and whatever strawberry pulp remains within it.
- Pour some of the filtered strawberry liquid into a test tube so that it is about ¼ full.
- Get the rubbing alcohol out of the freezer and very slowly pour a small amount down the inside of the test tube using a pipette. You want the alcohol to form a one-inch deep layer on top of the strawberry liquid.
- Try not to let the alcohol and strawberry liquid mix. The DNA should collect between the two layers and will look like long white stringy stuff.
- You can collect the DNA with a skewer, by dipping it in and pulling out the DNA.

Science Note:

The washing up liquid in the extraction layer will help break the strawberry cells open, allowing the DNA to spill out and then the salt helps create an environment where the different strands of DNA can gather together in a clump, making it easier for you to see them. DNA does not dissolve in alcohol, so it precipitates out of solution in big clumps.

Health and Safety Note:

Iso-propyl alcohol is highly flammable (R11), Irritating to the eyes (R36), and vapours may cause drowsiness and dizziness (R67).

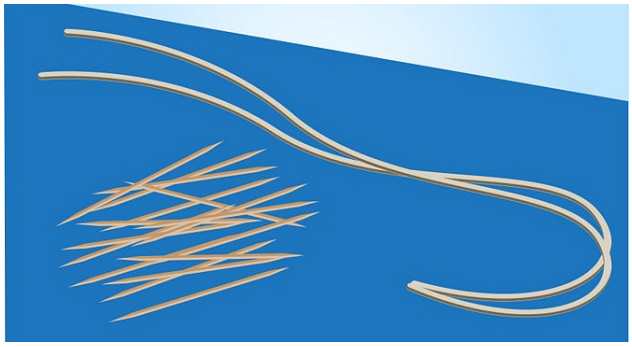
Week 2: Making DNA Models

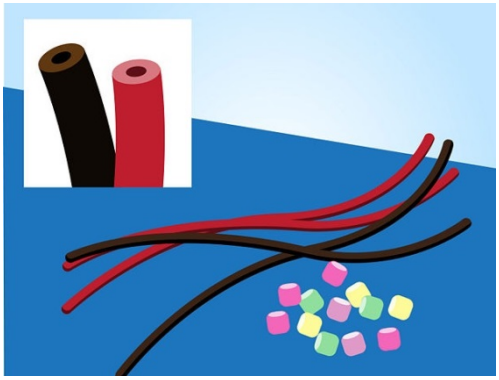
Equipment needed:

Black and red liquorice strands with hollow centres	String
Different coloured jelly babies or other assorted coloured sweeties	Toothpicks

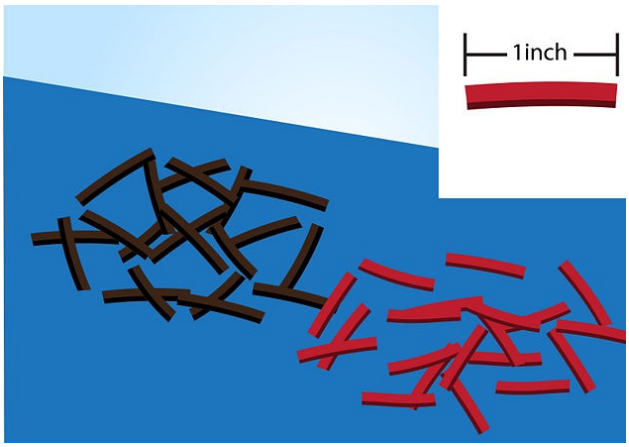
What to do:

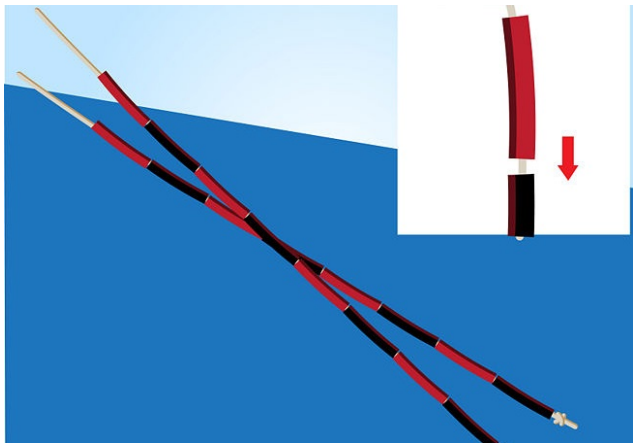
1. Gather the sweeties you plan to use, two lengths of string and some toothpicks. The pieces of string need to be the same length as each other. The black and red liquorice will make the sugar and phosphate sides of the DNA and the bases will be made using the jelly babies or other coloured soft sweets.



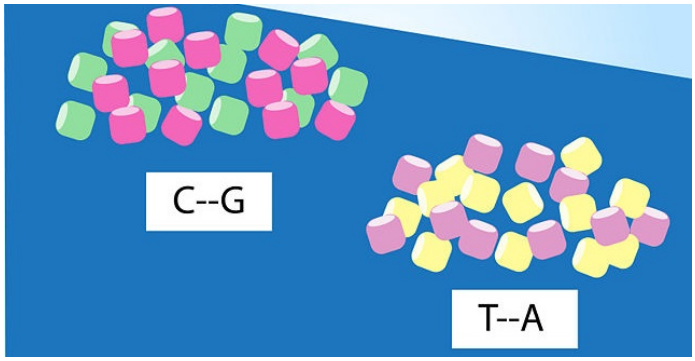


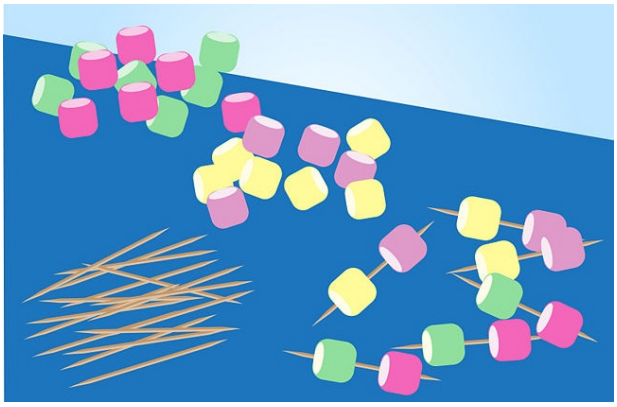
2. Cut the liquorice strands into about 1 inch long pieces. Tie knots in the bottom of the pieces of string and then thread the liquorice strands on in alternating colours. The different coloured liquorice symbolizes the sugar and phosphates that make up the DNA backbone. Therefore you need to pick one colour to be the sugar group, which the bases will attach to, and one colour to be the phosphates. The strands need to have the different colours added in the same order so that they line up when placed next to one another.



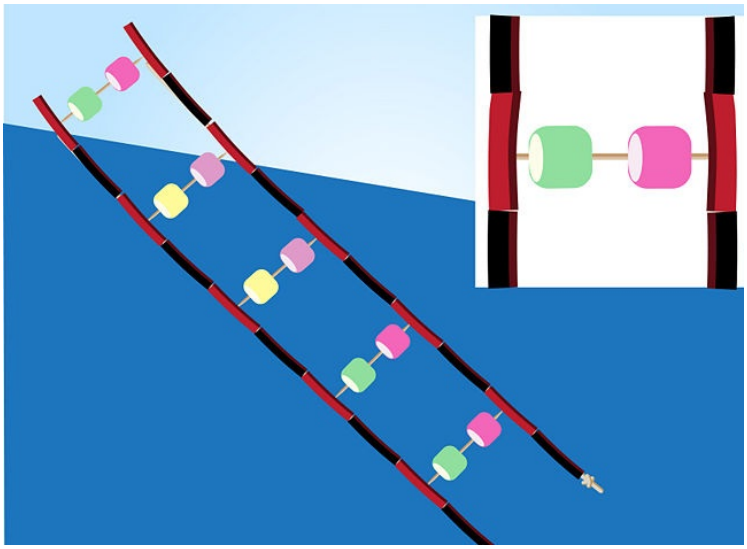


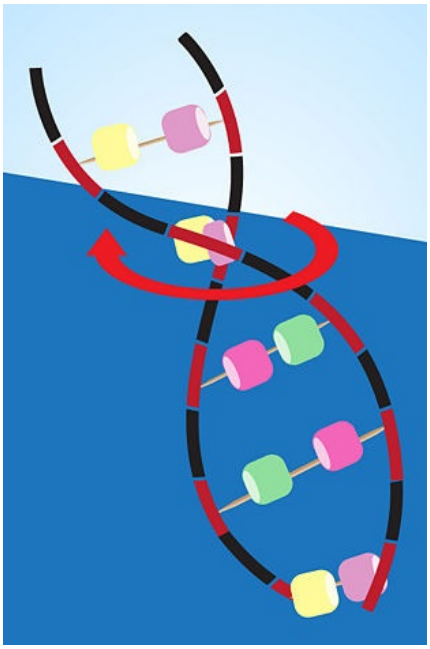
3. Pair off your coloured sweeties, so that you have designated bases. In DNA, Cytosine (C) pairs with Guanine (G) and Thymine (T) pairs with Adenine (A). The bases can pair C-G or G-C the order doesn't matter. However you cannot mix colours between base pairs. Neither A or T will pair with G or C. Attach your base pairs together using toothpicks, two bases per stick





4. Attach your base pairs to the liquorice strands. The base pairs should only be attached to the 'sugar' molecules; these are all the pieces of liquorice in the same colour (e.g. all red pieces). Once all the toothpick containing bases are attached, twist the strands anti-clockwise to make the DNA spiral like a true double helix.





Week 3: Electrophoresis *Agarose Gels and Pipette Practice*

Equipment needed:

Heat plate or Microwave	Agarose
Balance	Measuring cylinders
50 x TAE buffer	8 x Gel trays
Distilled water	Heat protective gloves
8 x Micropipettes	250ml Pyrex bottles
Pipette tips	Food colouring

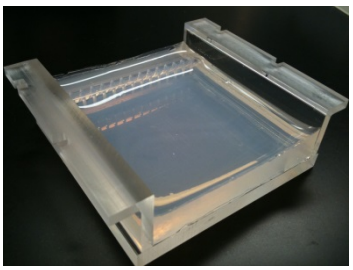
Prepare in Advance

- ***2.5 litres of 1xTAE buffer*** - 50ml of 50x TAE concentrate made up to 2500ml with distilled water
- ***1% Agarose gel*** - Weigh 2.5g agarose into 250ml **Pyrex** bottle and add 250ml of 1xTAE buffer

Melting the Agarose

- Gently swirl the Agarose / Buffer mixture to form a suspension
- ***Remove the lid*** of the bottle and place in a microwave and heat on full power.
- Boil and swirl the solution until all of the small translucent agarose particles are dissolved.
- Stopping the microwave and swirling the contents every 30 seconds helps dissolve the agarose faster. **CAUTION: Use heat protective gloves as boiling agarose can burn**
- Cool the molten Agarose to approx. 60ºC (or until the bottle feels warm but not hot to the touch)

Casting the Agarose Gel



- Level the gel caster using the levelling feet and the levelling bubble
- Disengage and slide the movable wall to the open end of the gel caster by turning and lifting the cam peg upwards
- Place the open edge of the gel tray against the fixed wall of the caster
- Slide the movable wall against the edge of the gel tray
- To seal the open tray ends engage the cam peg by turning and pressing down simultaneously
- Turn the peg until resistance is felt. This action seals the edges of the tray for casting
- Place the combs into the upper slot of the tray
- When the Agarose has cooled, pour 25ml of the solution slowly and carefully into the tray
- Leave to set for 15-20 minutes
  The agarose gels will dry out if left for more than a day, but can be stored overnight if left in the casting trays and submerged in TAE buffer.

Using a micropipette

Micro pipettes measure microliters (µl). The volume can be set by turning the ring, and they should always be used with a pipette tip

Setting the volume

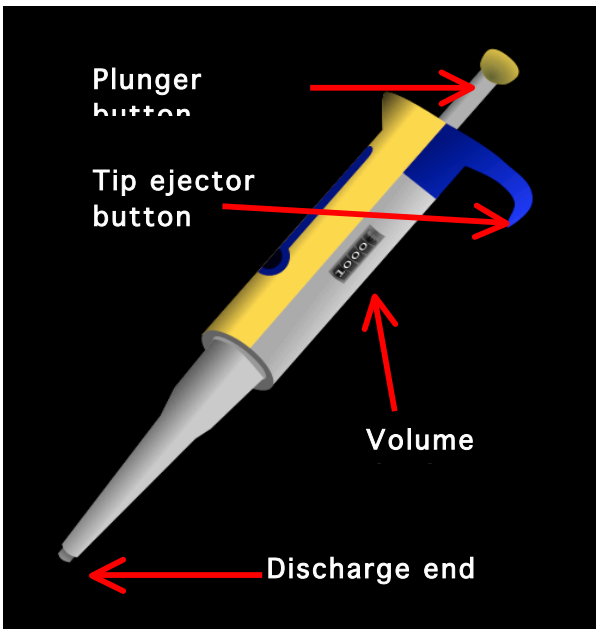
There are two different types of micropipette: a P20: which can measure volumes from 2-20 µl and a P200: which can measure volumes from 20-200 µl

To set the volume to **20 µl** on the **P20** the volume display will need to read like this from left to right:

2	0.	0

To set the volume to **20 µl** on the **P200** the volume display will need to read like this from left to right:

0	2	0



To load the sample

1. Insert a pipette tip; immerse the pipette with the tip into your sample tube. Press the plunger to the first stop and release back to the initial position.

To discharge the sample

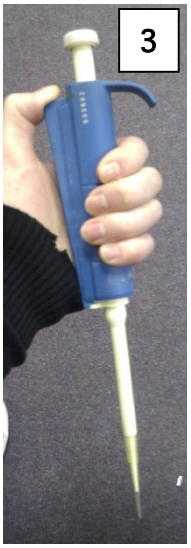
2. Press the plunger to the second stop

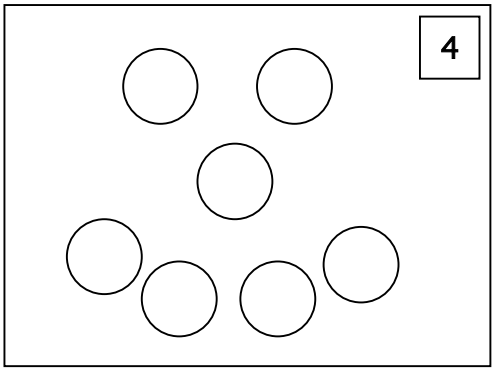
Repeat

3. Eject pipette tip by pressing down on the side button and the repeat from step 1 again.

Practice

4. Try making a line of dots or pipetting different coloured drops of food colouring into a shape like a smiley face.





Week 4:

Electrophoresis - *Running electrophoresis and discussing how it works*

Equipment needed:

50 x TAE buffer	Agarose gels (pre-prepared)
Micropipettes	Electrophoresis chamber and power packs x 8
Measuring cylinders	Gel trays x 8
Food colouring	

Setting up and running electrophoresis

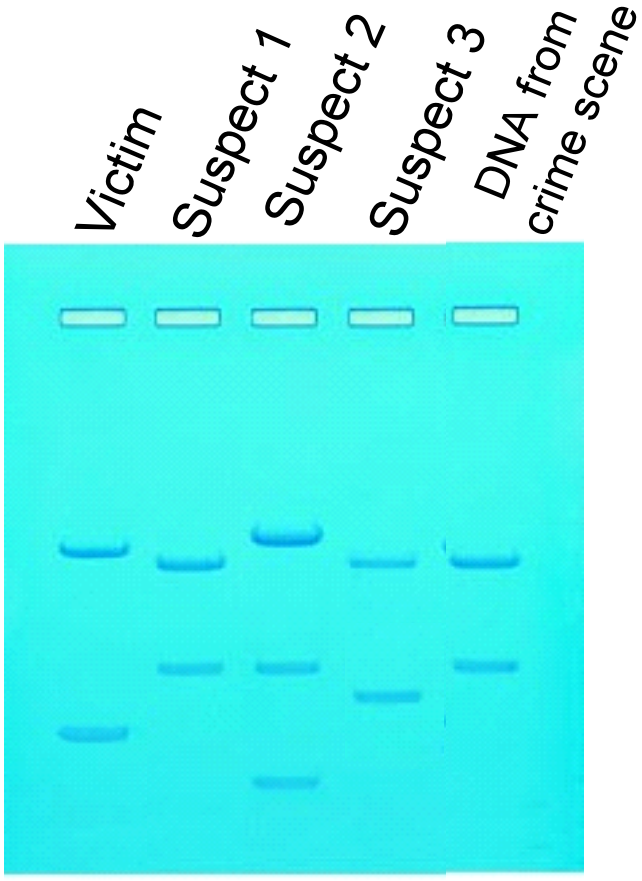
- Use your pre-prepared Agarose gels, or if they have dried out, make some new ones.
- Set up your gel tank with the positive electrode at the bottom nearest you
- Place the gel tray containing the solidified Agarose into the electrophoresis tank with the comb at the top
- Fill the tank with 250ml of 1X TAE buffer
- Carefully remove the comb to reveal the wells
- Load 20μl of one sample (food colouring) into each well using a pipette. Take care not to push the pipette tip through the bottom of the well
- The wells are often difficult to see. Placing the tank on a dark surface or a sheet of black paper can help
- Carefully place the lid on the gel tank; it will only fit on in the correct orientation.
- Attach the ends of the power leads to the appropriate ports on the power pack
- Set the power pack to 70V and press “run”. To check that the power pack is working, you should see bubbles near the electrodes.
- Let the electrophoresis run for about 20 minutes

How electrophoresis works

- In real life, fragments of DNA have different lengths
- And DNA can be visualised using a technique called gel electrophoresis, which separates DNA fragments according to their different lengths.
- Agarose gel has a texture like a sponge,(i.e. lots and lots of little holes)
- When an electric field is applied. The DNA that is negatively charged starts to snake through the holes towards the positive end of the tank.
- The shorter DNA fragments will migrate faster, the longer slower so that the DNA fragments will be separated by their length.
- In real life a stain is added to the gel, so that the DNA fragments become visible and appear like bands. These bands will be characteristic for each individual.
- However, the stain that would need to be used is a carcinogenic chemical.

This is why in this example we run food dye instead. The food dye will still give bands along the electrophoresis gel, as the different dyes within the colouring will separate out (similar to chromatography)

- A real life example of what a stained DNA gel electrophoresis sample would look like is below. These are the samples that real life forensic scientist would work with analysing crime scene
- If you would like a forensic style challenge you can use the exemplar sample below (right hand side) to try and work out which suspect is the murderer?



Week 5: All about you!

Before you start

Be aware of allergies and don't smell any of the scent pots if you are allergic to any of the scents (for example freesia)

Equipment needed:

Smelly pots x 6	Gene cards
Feely bags x 6	Various scents
Sound pots x 12	Cotton wool
Blindfold	Timers x 4
Shoe lace and lock block	Laminated activity cards
Small mirrors	Reaction time strips x 6
Sound pots board	Pen & paper – to write down results

How to run this activity

"All About You" is a self-investigative practical exploring how you rely on various senses and investigating how genetic traits affect physical characteristics.

There are seven challenges- you can do them in any order you wish

1. The blindfold test. Your eyes enable you to see, and so help to coordinate your movements. This challenge tests how you rely on your sight. Have a go at tying the shoe laces and putting the key in the lock, both with and without a blindfold on. Ask a partner to time you- which is faster? What about if you were to practice a few times?

2. The smell quiz. We rely on our noses to recognize certain smells, especially with things we eat. You are less likely to eat something that smells repugnant to you. Test your sense of smell by sniffing the black pots and seeing how many smells you can recognize.

3. The gene test. You are made up of genes, your genes determine how you look, and certain things that you can or cannot do. Have a look at the gene cards and look in the mirrors and work out which genetic traits you do or do not have.

4. Sound pairs game. This activity is based on the card game "memory". You need two players: take it in turns picking up two pots and shaking them; if they make the same sound the pots are kept by that player and removed from the playing board. If not, then they are placed back into their original positions and the next player takes their turn. This continues until no more pots are left on the board. The winner is the player who correctly identifies the most amount of matching pairs. Try and predict what is making the sounds. Now open the pots and have a look at what is making the noise. There should be four unique sounds. (Remember to put the lids back on the pots and mix them up on the board again when you're finished!)

5. Feely bags. Your skin is the largest organ in the body. You use it to touch and feel different things. You can also detect heat, pain and pressure through your skin. Put your hands into the feely bags- can you work out what is in each bag without looking? Open the bags up and see if your prediction was correct (remember to close the bags up again afterwards though!)

6. Taste test strips. This is a genetically linked taste test. Put the two strips of paper on your tongue, one strip at a time and write down what you taste (or don't taste!) one strip is a control and one is coated in a chemical called PTC (Phenylthiocarbamide).

7. Reaction time test. This test measures how quickly you can catch a strip of plastic when it is dropped between your fingers. Ask a partner to hold a reaction strip so the part marked 'Here' is resting just between your fingers and thumb as shown in the photo below. Then your partner drops it without telling you. Try and grab it as quickly as possible. The number on the scale above your finger is your reaction time in milliseconds. Try this test a few times; do you get faster each time?

Science Note:

- You will find some challenges easier than others and this could be due to a range of factors- some people naturally rely on certain senses more than others, for example some people might have a much stronger sense of smell.

- Certain genetic characteristics are inherited from your parents and will determine certain physical characteristics such as whether your earlobes are free or attached. Tongue rolling and right or left hand dominance are genetic predispositions you are born with but they can also be learnt over time.

- The taste test is entirely determined by genetic ability: some people will find the PTC bitter and some people will taste nothing at all. There is a single gene which codes for a protein found in our tongues. PTC will bind with this protein if present

and the person will taste it. If the protein is not present, PTC cannot bind and a person cannot taste it. Being able to taste PTC is a dominant trait; (you only need to inherit one copy of the gene to be able to taste it) so you would expect the majority of people to be able to taste it. You will also find of the people who can taste the PTC, some will find it excessively bitter- they will have two copies of the gene, so there are more binding sites available on the tongue to bind to.

- Interesting facts about PTC: people who can find PTC excessively bitter 'Super tasters' are more likely to find green vegetables bitter, but less likely to be smokers or be in a habit of drinking coffee or tea regularly.

Week 6: Evolution and Variation

Peppered Moth Activity

Equipment needed:

Sheet of white paper	30 newspaper circles (made from the hole punch)
Sheet of newspaper	30 white circles (made from the hole punch)
Forceps	Hole punch
Timer	

Background:

This is an activity designed to simulate how predators locate prey based on the real life example of the 'peppered moth'. In any habitat, predators will search for prey. The prey better adapted to the environment will thus live to pass on their genes to the next generation. In this activity you are the predator (a bird) and your prey are the peppered moths.

How to run the activity:

- Place a sheet of white paper on the table and have one person spread 30 white circles and 30 newspaper circles over the surface while the other person isn't looking.
- The "predator" will then use forceps to pick up as many of the circles as he or she can in 15 seconds.
- The number that are left are doubled to represent the next generation
- This trial will be repeated with white circles on a newspaper background, newspaper circles on a white background, and newspaper circles on a newspaper background. Record the data in chart below.

Populations starting on a white background				
	Starting population		Final Populations (how many of the originals were left)	
Generation	Newspaper	White	Newspaper	White
1	30	30		
2				
3				
4				
5				
Populations starting on a Newspaper background				
	Starting population		Final Populations (how many of the originals were left)	
Generation	Newspaper	White	Newspaper	White
1	30	30		
2				
3				
4				
5				

Science Note:

The above activity is based upon the evolution of the peppered moth over the last 200 years. There are different varieties of the peppered moths including light coloured and dark coloured variations. Originally there was a large population of light coloured peppered moths in the UK, which meant that they were well camouflaged against regular tree bark and lichens and hard to spot for the predators (birds) that hunted them. However during the Industrial revolution (1760-1840) due to excessive pollution the trees became blackened by soot, this meant that the previously well camouflaged moths were now very visible to the predators, and therefore high proportions of the light coloured moths died out. However peppered moths born with the 'dark coloured' gene became better adapted to the new environment, as they camouflaged in better with the surroundings, therefore they bred and passed on this gene to their offspring, causing the population of dark coloured moths to exceed the population of light coloured moths.

Duck Design

Equipment needed:

Chopsticks	M&M sweets
BBQ tongs	Jelly worms
Spoons	Juice drinks
Straws	Fish biscuits

Background:

This is an activity designed to simulate how predators are adapted to eating their prey. There are four kinds of imaginary ducks, each of which have a different kind of beak. The ducks live on four different islands, and each island has a different food source:

Choppy Duck

BBQ Duck

Scoopy Duck

Insect Island

Worm Island

Sucky Duck

Nectar Island

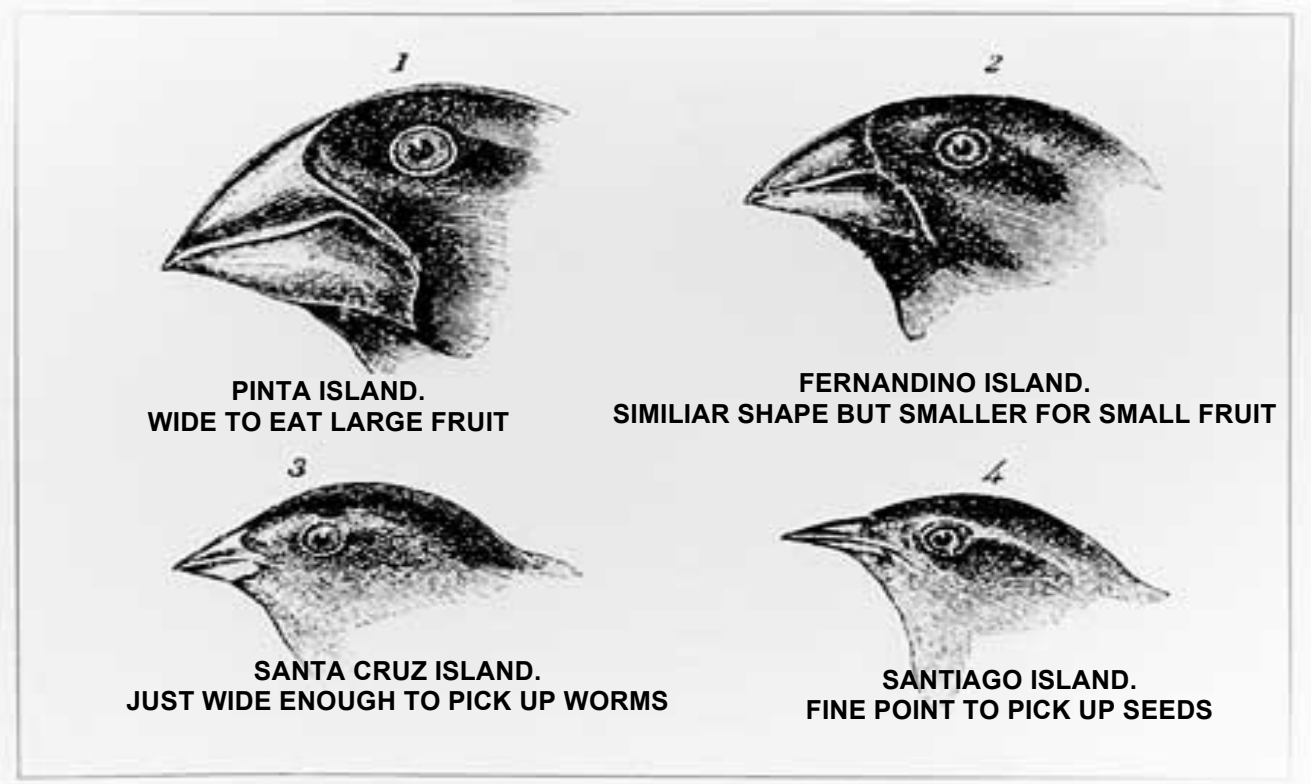
Fish Island

How to run the activity:

- Experiment with the various beaks and food sources to work out which duck is best suited to living on which island?
- Which ducks could go and live on a different island if their own food source ran out?

Science Note:

The above activity is based upon 'Darwin's finches' and how he later evolved his theory of evolution by natural selection. What Darwin discovered on a trip to the Galapagos Islands is that species of the same bird living among the islands all have very different shaped beaks, and this was due to 'Natural Selection'. Due to different food sources being more available on different parts of the island, different sized and shaped beaks were more 'adept' at foraging for certain food types (e.g. berries, grubs etc.) because of this, birds with naturally better beaks survived better in different areas of the islands and therefore reproduced and passed on this trait (DNA) to their young. Birds that were not well suited to foraging for a certain food type would die out or leave that part of the island. Over time this resulted in very clear differences amongst the finches or what is known as evolution.



Week 7: Clippy Island

Equipment needed:

Plastic trays	Green mung beans
Small cups	Red kidney beans
Bulldog clips of assorted sizes (big, medium and small)	Black beans
Stop watch/ timer	

Background:

This is an activity designed to simulate 'survival of the fittest' whereby animals better suited to an environment will survive and reproduce- growing in population and animals not well suited will die out and become extinct.
In this activity, you become a bird known as a 'spring beak' and will live in an imaginary place called 'Clippy island'. The spring beaks have three different sized beaks; big, medium and small

How to run the activity:

- This activity is best carried out in groups of 3-4. Each person will need a different sized bulldog clip: small, medium or large. Each person will also get a paper cup- this represents their stomach. Each group will need a tray- this represents the island.
- Start off by filling the tray with only one food type- the small green mung beans. The object of the game is to 'eat' as much as possible by picking up beans and putting them in the cup using the bull dog clips.
- There are a few rules to feeding: 1) You can only feed for the designated amount of time per season 2) You can only pick up one bean at a time 3) You cannot scoop up beans using the cup or use the bulldog clip like a shovel.
- Different spring beaks have different food requirements which are based on their beak size; these are show in the table below.
- Different food sources are worth different amounts of calories, these are also shown below.
- For each season, fill in the results in the chart below. In between each season you must empty your cup and start again. If a spring beak dies in a season they do not come back in again, unless you restart the game from scratch, or take part in a different trial. If a spring beak eats enough beans to reproduce, they get another bull dog clip of the same size and can either work both themselves or nominate someone else to become that spring beak (maybe someone else in their group whose own spring beak died).
- Run the activity over four 'seasons' at the end of the season count up how many spring beaks of each type you are left with.
- Run the activity from the start again; start off with one of each type of spring beak but this time, introduce a new food source- black beans as well as green beans. Complete four seasons and analyse how the population of different spring beaks changes this time.
- Run the activity for a third time and this time add red kidney beans to the island as well. Analyse how the populations of different spring beaks changes again.

Food type	Calories (score)
Green beans	2
Black beans	5
Red beans	10

Beak size	Die	Survive	Survive & Reproduce
Big	<70 calories	70 calories	140
Medium	<40 calories	40 calories	80
Small	<20 calories	20 calories	40

Trial 1. Food source- green mung beans only				
	What size beak did you have?	How many beans did you eat?	How many calories?	Did you die, survive or reproduce?
Season 1				
Season 2				
Season 3				
Season 4				

Number of spring beaks at the start	
Big	
Medium	
Small	

Number of Spring beaks at the end	
Big	
Medium	
Small	

Trial 2. Food source- green mung beans & black beans					
	What size beak did you have?	How many beans did you eat?		How many overall calories?	Did you die, survive or reproduce?
		Green	Black		
Season 1					
Season 2					
Season 3					
Season 4					

Number of spring beaks at the start			**Number of Spring beaks at the end**	
Big			**Big**	
Medium			**Medium**	
Small			**Small**	

Trial 3. Food source- green mung beans & black beans & red kidney beans						
	What size beak did you have?	How many beans did you eat?			How many overall calories?	Did you die, survive or reproduce?
		Green	Black	Red		
Season 1						
Season 2						
Season 3						
Season 4						

Number of spring beaks at the start			**Number of Spring beaks at the end**	
Big			**Big**	
Medium			**Medium**	
Small			**Small**	